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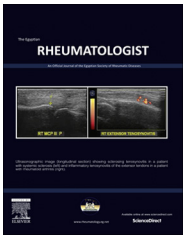

ORIGINAL ARTICLE

Subclinical pronator syndrome in patients with carpal tunnel syndrome: An electrophysiological study

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KEYWORDS

Carpal tunnel syndrome;
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Anterior interosseous/median score

Abstract *Aim of the work:* The aim of the present study was to detect subclinical pronator syndrome (PS) in patients with carpal tunnel syndrome (CTS) with the utility of the anterior interosseous/median (AIM) score.

Patients and methods: The present study included 90 clinically diagnosed CTS hands and 60 asymptomatic hands of healthy volunteers as a control group. Clinical examination was done for all patients. The following tests were done: (1) Sensory nerve conduction studies: median and ulnar nerves; (2) Motor nerve conduction studies: median and ulnar nerves as well as the anterior interosseous nerve recording the pronator quadratus muscle with calculation of the AIM score. AIM score is a ratio of the antecubital motor latency of the anterior interosseous nerve to that of the median nerve.

Results: There were 71 CTS hands (78.9%) with a median distal latency (DL) exceeding the reference value and the AIM score was decreased in 63 (70%) of them. Eight hands (8.9%) had a prolonged median DL associated with an AIM score within the reference range raising the probability of having PS. Five (5.6%) of these eight hands had electrophysiological findings in consistency with an established PS. The sensitivity of AIM for the concomitant detection of PS with CTS was 100% and the specificity 95.4%. None of the controls had PS.

Conclusions: Subclinical PS is found in CTS patients and could be searched for electrophysiologically in those patients with evidence of moderate to severe degrees of CTS and the AIM score is useful in this aspect.

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1. Introduction

The median nerve is liable to entrapment at several sites along its course [1,2]. Its entrapment is more common distally at the wrist and is known as carpal tunnel syndrome (CTS) [3–8]. It can occur uncommonly proximally at the elbow which is

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known as pronator syndrome (PS) and under the ligament of Struthers [9–13]. Median nerve entrapment under ligament of Struthers is very rare [1]. The most common site of median nerve entrapment in PS is at the fibrous band between the two heads of the pronator teres muscle [1,14]. Both PS and CTS can coexist [15,16] forming a sort of double crush syndrome. In this situation, if the PS is mild or not obvious, it can be clinically missed [16,17]. The unmanaged associated PS may lead to unsatisfying results of carpal tunnel decompression surgery [18]. The PS can present by manifestations similar to CTS [17,19]. Advanced cases of PS can be easily distinguished and differentiated from CTS clinically. This includes weakness and wasting of the forearm median innervated muscles with hypoesthesia over the territory of the median nerve [1]. The use of the anterior interosseous/median (AIM) score can be useful in the diagnosis of PS associated with CTS [20]. There are no studies that assessed the association of PS with CTS electrophysiologically. The aim of the present study was to detect the subclinical pronator syndrome (PS) in patients with carpal tunnel syndrome (CTS) with the utility of the anterior interosseous/median (AIM) score.

2. Patients and methods

2.1. Patients

The present cross sectional study included 81 patients with CTS who were consecutively recruited from those attending the outpatient clinic of Physical Medicine, Rheumatology and Rehabilitation Department, Faculty of Medicine, Alexandria University and 49 apparently healthy volunteers as a control group. The volunteers consisted of medical staff, their relatives and patients' relatives.

Clinical diagnosis of CTS was based on the presence of at least one of the following primary symptoms: (i) the presence of numbness, tingling or paresthesia in the median nerve distribution and wrist pain, (ii) the symptoms are precipitated by repetitive hand activities and relieved by resting, rubbing and shaking the hand, and (iii) the presence of nocturnal awakening by these sensory manifestations. The clinical diagnosis of CTS was supported by the presence of positive Tinel's sign and/or Phalen's sign [21]. Exclusion criteria included diabetes mellitus, endocrine disorders, metabolic disorders, rheumatological disorders, neurological disorders which include peripheral neuropathy, cervical radiculopathy, and weakness and wasting of forearm median innervated muscles (which are characteristic manifestations of PS); and other conditions predisposing to CTS as pregnancy or previous wrist fracture [22–24]. The study was explained to the participants and an informed consent was given by each. The study had been approved by the ethics committee of the Faculty of Medicine, Alexandria University, Egypt.

2.2. Methods

Patients were clinically evaluated. The standardized semi-quantitative clinical History–Objective (Hi–Ob) scale was used to assess the CTS severity by integrating symptoms with clinical features [25]. The Hi–Ob scale has 5 stages of severity. Stage 1 (mildest form): Presence of nocturnal paresthesia only. Stage 2: Diurnal paresthesia with no objective sensory deficits. Stage 3: Sensory deficit in the presence of nocturnal or diurnal symptoms. Stage 4: Motor weakness with mild atrophy of median innervated thenar muscles. Stage 5: Complete atrophy or plegia of median innervated thenar muscles [25].

Electrophysiological studies were conducted on a NIHON KOHDEN Neuropack MEB-7102 mobile unit with a two channel evoked potential/EMG measuring system (Nihon Kohden Corporation, Tokyo, Japan). Skin temperature at the site of the recording electrode was maintained around 32–34 °C using hot packs. The ground electrode was placed between the recording electrodes distally and the stimulation site proximally. Conduction distances were measured by a measuring tape with 1 mm precision [5]. The study included the following:

(A) *Sensory nerve conduction study (NCS):* For all sensory NCSs the following were applied: the sweep speed was 2 ms/division and the sensitivity was 10 μV/division. The filter bandwidth was 20 Hz–2 kHz. The bipolar stimulator had a production current ability of 50 mA. The stimulation frequency was 0.2 Hz and pulse duration was 0.2 ms. Signal averaging was applied. Responses were recorded twice and superimposed to ensure reproducibility. Supramaximal stimulation was ensured. Measurements of sensory nerve action potential (SNAP) included onset latency (ms), amplitude (μV) and conduction velocity (CV) (m/s) [1,5].

Sensory NCS of the median and ulnar nerves was performed using the antidromic technique: An active recording surface disc electrode was attached to the palmar aspect of the proximal phalanx of the 2nd and 5th fingers (for the median and ulnar nerves respectively) with the reference surface disc electrode 3 cm distal on the corresponding fingers. Electrical stimulation was done at the wrist 14 cm proximal to the active recording electrode using a bipolar stimulator between flexor carpi radialis and palmaris longus tendons (for median nerve) and just lateral to the flexor carpi ulnaris tendon (for the ulnar nerve). The amplitude and CV were taken for analysis [1,5,26].

(B) *Motor NCS:* For all motor NCSs the following were applied: The sweep speed was 5 ms/division and the sensitivity was 5 mV/division. The filter bandwidth was 10 Hz–10 kHz. The bipolar stimulator had a production current ability of 50 mA. The stimulation frequency was 0.2 Hz and pulse duration was 0.2 ms. Measurements of compound muscle action potential (CMAP) included distal latency (DL) (ms), amplitude (mV) and CV (m/s). Supramaximal stimulation was ensured [26].

Motor NCS of the median and ulnar nerves: An active recording surface disc electrode was attached over the abductor pollicis brevis and abductor digiti minimi muscles bellies (for median and ulnar nerves respectively) and the reference surface disc electrode over the 1st and 5th finger metacarpophalangeal joints respectively. Electrical stimulation of the median nerve was done at 7 cm proximal to the active recording electrode at the wrist between the flexor carpi radialis and palmaris longus tendons and at the antecubital crease at the medial border of the biceps brachii tendon; for the ulnar nerve electric stimulation was just lateral to the flexor carpi ulnaris tendon, and 4 cm distal to the medial epicondyle. The distal latencies, median antecubital latency, amplitude and CV were taken for analysis [26].

Motor nerve conduction study of anterior interosseous nerve: The active recording surface disc electrode was placed just over the dorsum of the forearm in-between the ulna and radius

about 3 cm proximal to the ulnar styloid process (for recording the pronator quadratus muscle CMAP) and the reference surface disc electrode was placed on the medial aspect of the wrist over the ulnar styloid process posteriorly. Electrical stimulation of the median nerve was done at the antecubital crease at the medial border of the biceps brachii tendon. The antecubital latency, CMAP amplitude and AIM score were taken for analysis [20,26,27].

The AIM score is a ratio of the antecubital latency of the anterior interosseous nerve (recording pronator quadratus muscle) to the antecubital latency of the median nerve (recording abductor pollicis brevis muscle). A decrease in the ratio indicates CTS, an increased ratio suggests anterior interosseous nerve entrapment while a normal ratio suggests a normal status, but the presence of a normal ratio in a patient with CTS and prolonged median motor DL suggests a combination of CTS and PS [20].

Electrophysiological support of established PS in patients with CTS involved evidence of conduction block (drop in CMAP amplitude >50% between wrist and antecubital median CMAPs) [1]. *Electrophysiological grading of the severity of CTS* was rated according to Bland scale [27]. Bland scale is divided into 6 different grades: Grade 0: shows no evidence of CTS electrophysiologically. Grade 1 (very mild): Presence of two abnormal sensitive comparative tests. Grade 2 (mild): Delayed median sensory CV. Grade 3 (moderate): Delayed median motor DL (<6.5 ms) with preserved median SNAP. Grade 4 (severe): Delayed median motor DL (<6.5 ms) with absent median SNAP. Grade 5 (very severe): Delayed median motor DL (>6.5 ms). Grade 6 (extremely severe): Delayed median motor DL with decreased median CMAP amplitude (<0.2 mV) [28].

Statistical analysis was done by using the Statistical Package of Social Science (SPSS version 17) software. Descriptive measures [count, frequency, minimum, maximum, mean and standard deviation (SD)] as well as analytic measures (*t*-test and Pearson Chi-square test) were used. Statistical significance was assigned to any P value at $\leqslant 0.05$. The sensitivity was calculated as the number of patients with AIM score of normal ratio suggesting PS with electrophysiological evidence of PS concomitant with CTS/total number of patients with electrophysiological evidence of PS concomitant with CTS. The specificity was calculated as the number of patients with AIM score of decreased ratio not suggesting PS and without electrophysiological evidence of PS concomitant with CTS/total number of patients without electrophysiological evidence of PS concomitant with CTS with prolonged median DL.

3. Results

The present study included 90 clinically diagnosed CTS hands that were obtained from 81 patients [66 women (81.5%) and 15 men (18.5%)]. Their mean age was 38.94 ± 10.49 years (ranged from 18 to 63 years). The median Hi–Ob scale was grade 2 (ranged from 1 to 5). Grade 3 Hi–Ob scale was the commonest grade (41.1%). The distribution of CTS patients according to Hi–Ob scale revealed grade 1 in 15 hands (16.7%), grade 2 in 33 hands (36.7%), grade 3 in 37 hands (41.1%), grade 4 in 3 hands (3.3%) and grade 5 was present in 2 hands (2.2%). The median Bland scale was grade 3 (ranged from 2 to 5): 19 CTS hands (21.1%) had grade 2, 40 hands (44.5%) had grade 3, 16 hands (17.8%) had grade 4 and 15 hands (16.6%) had grade 5. Bilateral affection was present in 16 patients (19.7%). The control group consisted of 60 asymptomatic hands that were obtained from 49 healthy individuals [35 women (71.4%) and 14 men (28.6%)]. Their mean age was 36.66 ± 10.56 years (ranged from 18 to 65 years). There were no statistically significant differences between patients and the control group as regards gender ($X^2 = 1.78$, $P = 0.182$) and age ($t = -1.299$, $P = 0.196$).

The clinical characteristics of the patients are summarized in Table 1. Details of the electrophysiological studies results among patients and the control group are presented in Table 2. Reference values for all electrophysiological tests parameters obtained from the control group are presented in Table 3.

There were five hands (5.6%) that had electrophysiological findings in consistency with an established PS. All of them had evidence of conduction block in the median CMAP between the wrist and antecubital area. These five hands were from five different patients. The clinical characteristics of these patients are tabulated in Table 4. As regards the AIM score, it was found that CTS hands [19 hands (21.1%)] with a Bland scale of 2 (i.e. they had median DL within the reference value) had an AIM score within the reference range. The CTS hands [71 hands (78.9%)] with a Bland scale more than 2 (i.e. they had median DL exceeding the reference value) had decreased AIM score in 63 hands (70%). The remaining eight hands (8.9%) with prolonged median DL associated with the AIM score within the reference range had a probability of having PS; five (5.6%) of these eight hands had established PS. The remaining three hands (3.3%) had no electrophysiological evidence of an established PS (Fig. 1). Thus, the sensitivity of AIM for the detection of PS concomitant with CTS [with delayed median DL (Bland scale more than 2)] was 100% and specificity was 95.4%.

4. Discussion

Median nerve entrapment can occur distally as CTS or proximally as PS. Advanced cases of PS can be easily distinguished and differentiated from CTS clinically. Its clinical picture includes weakness and wasting of the forearm median innervated muscles with sensory changes along the territory of the median nerve [1,29,30].

In the current study, there were 5 CTS hands (5.6%) with associated electrophysiological evidence of established PS. This was present on inclusion of patients with clinically obvious CTS with no clinical features or manifestations suggesting PS. The median Hi–Ob scale of the CTS hands was 3, which is an indicator of more severe CTS symptoms and signs, while the median of Bland scale of these hands was 5, which is an indicator of more electrophysiological severity of CTS. Consequently, the presence of advanced CTS manifestations and more CTS electrophysiological severity are indicators for searching for a proximal median entrapment neuropathy. This is a sort of double crush syndrome [31]. When there is a single lesion along the course of a nerve, it predisposes that nerve to a second lesion further along its course especially when it passes in an anatomical narrow segment [32]. In the present study, patients with very mild and mild CTS electrophysiologically had no concomitant PS in contrast to patients with more severe CTS. This confirms that overuse and repetitive

Table 1 Characteristics of the carpal tunnel syndrome patients and control.

Characteristics	CTS patients (n = 81) (90 hands)	Control (n = 49) (60 hands)	P
Women	66 (81.5)	35 (71.4)	0.18
Age (years)	38.94 ± 10.49	36.66 ± 10.56	0.196
Side (right/left)	55 (61.1)/35 (38.9)	32 (53.3)/28 (46.7)	0.34
Disease duration (months)	18.18 ± 15.87	–	–
Hi–Ob scale	2 (1–5)	–	–
Bland grading	3 (2–5)	–	–

Results are presented as number (percentage), mean ± SD or median (range). CTS, carpal tunnel syndrome; Hi–Ob scale, clinical History–Objective scale. P is significant at ⩽0.05.

Table 2 Electrophysiological study results among carpal tunnel syndrome patients and control.

Nerve conduction study parameters mean ± SD	CTS patients (n = 81) (90 hands)	Control (n = 49) (60 hands)	t	P
Median DL (ms)	5.35 ± 1.35	3.57 ± 0.42	−9.88	< 0.0001*
Median motor antecubital L (ms)	9.06 ± 1.56	7.10 ± 0.61	−9.21	< 0.0001*
Median motor CV (m/s)	58.95 ± 7.35	60.78 ± 7.18	1.43	0.156
Median CMAP amp at wrist (mV)	6.64 ± 2.73	9.35 ± 3.01	5.71	< 0.0001*
Ulnar motor DL (ms)	2.84 ± 0.36	2.78 ± 0.31	−0.98	0.328
AI antecubital L (ms)	3.70 ± 0.38	3.72 ± 0.32	0.30	0.765
AIM score	0.41 ± 0.05	0.52 ± 0.04	12.54	< 0.0001*
AI CMAP amp (mV)	2.09 ± 0.82	2.14 ± 0.86	0.4	0.690
Median sensory CV (m/s)	38.94 ± 3.71	55.81 ± 5.71	19.5	< 0.0001*
Median SNAP amp (μV)	16.44 ± 9.10	25.64 ± 7.74	6.02	< 0.0001*
Ulnar sensory CV (m/s)	58.75 ± 6.05	58.91 ± 6.12	0.15	0.879

CTS, carpal tunnel syndrome; DL, distal latency; L, latency; CV, conduction velocity; CMAP, compound muscle action potential; amp, amplitude; AI, anterior interosseous; AIM, anterior interosseous/median, SNAP, sensory nerve action potential.
* P is significant at ⩽0.05.

Table 3 The determined reference cut-off values for different electrophysiological studies.

Nerve conduction study parameters	NL
Median DL (ms)	4.4
Median motor CV (m/s)	46.4
Median CMAP amp at wrist (mV)	3.3
AI antecubital L (ms)	4.4
AIM score	0.44–0.6
AI CMAP amp (mV)	0.4
Median sensory CV (m/s)	44.4
Median SNAP amp (μV)	10.2

NL, upper (latency) or lower (CV) limit of normal; DL, distal latency; CMAP, compound muscle action potential; CV, conduction velocity; amp, amplitude; L, latency; AI, anterior interosseous; AIM, anterior interosseous/median; SNAP, sensory nerve action potential.

movement of the upper limb (i.e. in the form of excessive work rates or duration of work, inadequate work breaks or rest periods and monotonous work without task variations) are the predisposing factors of CTS as well as PS [33–35].

The AIM score is a method used to assess median nerve lesions distally, proximally and both. In the present study, the sensitivity of AIM for the detection of PS concomitant with CTS [with delayed median DL (Bland scale more than 2)] was 100% and specificity was 95.4%. This is an indication of the usefulness of AIM score (a non-invasive technique) in the assessment of median nerve proximally among patients with CTS and giving an alert for detection of concomitant subclinical PS with CTS. This may also help in the proper diagnosis and management of CTS patients. The considerable percentage of patients, who were found to have both pathologies in the present study, can be an indicator that subclinical and mild PS is a health problem which can be predisposed by the same predisposing factors of CTS in the form of overuse and repetitive movement of the upper limb [33,34]. There were no patients with an elevated AIM score. This indicates that there were no patients that had anterior interosseous nerve lesion among the present patients. The surface recording of the anterior interosseous nerve CMAP was found to be as accurate as the needle recording [36]. Shafshak and EI-Hinawy reported the mean of anterior interosseous latency as 3.15 ± 0.47 ms and upper limit of normal as 4.1 ms, which was comparable to its reference value that was obtained in the current study [36].

Patients with PS should be treated by rest/immobilization, physical modalities, and work modifications with instructions. These will allow the condition to be resolved or even remain stationary without progression to pain in the forearm with weakness of the forearm median innervated muscles [17,29].

In the current study, median SNAP and CMAP amplitude were decreased among the CTS patients in comparison to the control. This could be due to the focal slowing of median nerve fibres across the carpal tunnel, axonal loss of median nerve

Table 4 Characteristics of carpal tunnel syndrome patients with confirmed electrophysiological evidence of pronator syndrome.

Characteristics	CTS patients with established PS (n = 5) (5 hands)
Women	4 (80)
Age (years)	43 (35–63)
Side (right/left)	4 (80)/1 (20)
Disease duration (months)	12 (4–48)
Hi–Ob scale	3 (2–4)
Bland grading	5 (3–5)
Normal AIM score	5 (100)

Results are presented as number (percentage) or median (range). CTS, carpal tunnel syndrome; PS, pronator syndrome; Hi–Ob scale, clinical History–Objective scale; AIM, anterior interosseous/median.

fibres in advanced cases of CTS or the presence of proximal median entrapment neuropathy (i.e. PS) [1,21].

The current study is in accordance with the study of Rosenberg [20]. He reported that CTS is associated with decreased AIM score. The mean of AIM score was 0.6 ± 0.06 and their cut-off reference value was 0.52–0.68 which was slightly higher than that obtained in the current study. This can be due to difference in the technique of recording the anterior interosseous CMAP. He recorded the CMAP from the pronator quadratus by using a monopolar electrode which is more accurate in CMAP latency assessment and on the contrary it is an invasive technique. Rosenberg studied ten patients with mild CTS and their mean AIM score was lower than the reference value which was not in accordance with the current study where all mild cases of CTS had a normal AIM score. This can be due to difference in the definition criteria used for mild CTS [20].

The present study is in agreement with Olehnik et al. in the existence of concomitant PS with CTS [10]. They studied median nerve compression in the proximal forearm and reported that 47.2% of their patients had prior ipsilateral carpal tunnel releases for CTS that did not improve the patients' complaints. They reported that 32.5% of the assessed limbs had abnormal electrophysiological tests consistent with proximal median neuropathy and that 73.5% of those who had a prior failed carpal tunnel release had complete or partial relief after median nerve decompression in the proximal forearm [10].

The current study is considered to be the initial study that assessed the coexistence of subclinical PS with CTS among CTS patients with variable degrees of electrophysiological severity. The non-invasive nature of the utilized techniques makes them easy to be applied in every patient complaining of paraesthesia along the territory of median nerve with symptoms suggesting proximal median neuropathy. Further studies are recommended to verify the results of the current study on a larger scale. The current study had some limitations. First; there were no CTS hands with extremely severe CTS (grade 6 Bland scale). Second; electromyographic study of the forearm median innervated muscles was not done to prove the presence of electromyographic evidence of PS. It is not applicable to assess these muscles among CTS patients with no associated clinical evidence of proximal median neuropathy. This is not recommended by the American Association of Electrodiagnostic Medicine practice parameters [37]. The current study had an exclusion criterion of the absence of any clinical evidence of PS (weakness and wasting of forearm median innervated muscles). It was not ethical to assess patients with

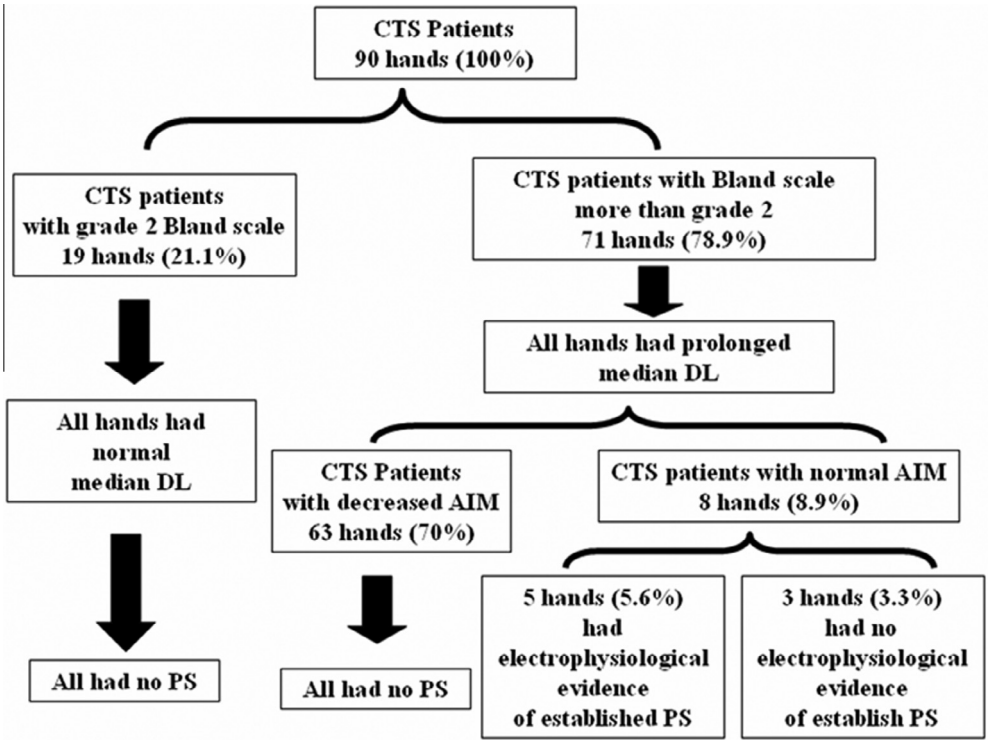

Figure 1 A flow chart illustrating the results of the electrophysiological studies among the carpal tunnel syndrome patients (n = 81).

CTS by electromyography which is an invasive technique and not recommended [37].

In conclusion, Subclinical PS is found in CTS patients and could be searched for electrophysiologically in those patients with evidence of moderate to severe degrees of CTS and the AIM score is useful in this aspect.

Conflict of interest

None declared.

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